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Possibility to Reduce Drudgery and Time in Harvesting Individual Ripe Fruits of *Jatropha curcas* Linn by Whole Bunch Harvesting

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ABSTRACT

A study was conducted to determine Jatropha fruits ripening uniformity on its tree and bunches characteristics. To get more information about its ripening off, the tree characteristics a respiration pattern was determined. The data were collected on five trees for each ten selected accessions (n=50) for fruit ripening uniformity on its trees study and fifteen bunches for each seven selected accessions (n=105) for fruits bunches ripening uniformity study at two jatropha pilot projects at Sabah state of Malaysia at the end of March 2009 when the trees were exactly one year old. This study confirmed that heterogeneous ripening occured in all jatropha accessions and within individual jatropha bunches. Respiration tests confirmed that jatropha is a climacteric fruit. The results showed an upsurge in CO_2 production at the end of ripening and at the beginning of senescence. This study has revealed indications of the possibility to harvest jatropha fruit in bunches rather than harvesting individual ripe fruit, which could potentially improve harvest efficiency by reducing harvesting time and drudgery.

Keywords: ripening, respiration rate, post-harvest, climacteric

INTRODUCTION

The drudgery and time requirements in harvesting jatropha fruits has been highlighted in many publications (GEXSI, 2008; Hambali *et al.*, 2007; Jim, 2009). The main harvesting and postharvest problems of jatropha fruits is that in any single branch the fruits ripen at different times leading to laborious and time consuming harvesting as farmers have to select the ripe fruits only or fruits have to be harvested manually at regular intervals (Heller, 1996; Biswas *et al.,* 2006). Jatropha fruits are still harvested by hand in small scale plantations. Jatropha seeds in Myanmar's eight million acres (3.24 million hectares) were reported to be rotting on the farm due to poor harvesting technology (Jim, 2009). Mechanical harvesting of jatropha was considered to be impossible due to the non uniformity of fruit ripening.

Indications of harvesting time and maturity are still a difficult issue for this crop. Reports of harvesting time for this crop based on high oil extraction rate are inconsistent. Heller (1996), Nurcholis and Sumarsih (2007), Priyanto (2007), and Hambali *et al.* (2007) recommended that fruits are harvested at 90 days; while Santoso (2008) and Annarao *et al*. (2008) recomended at 55 and 37 days after anthesis, respectively. In addition, the date and length of harvest period is likely to vary according to seasonal conditions of a given locality (Kaushik, 2006). Therefore, bunch characteristics are now the focus as a harvesting indicator in recent literature. It is recommended that bunches are ready for harvest when 50% (Hambali *et al.* 2007), 60 -70% (Nurcholis and Sumarsih, 2007) and 75% (Priyanto, 2007) of fruits in a single branch (are) ripe.

If bunch characteristics are to serve as an indication for harvesting time then the next problem would be to solve the problem posed by variations in the fruits ripening stage after harvest. The harvested fruits that are yet to reach the required ripening stage for high oil extraction rate might require postharvest handling such as ripening treatments with external ethylene gas treatment. However, no such treatments are available for jatropha at this time. It is important to note that there are physiological and biochemical ripening differences between fruits on (*in situ*) and off the tree. According to Wills *et al.,* (1998) the development and maturation of fruits is complete only when it is attached to the plant, but ripening and senescence may proceed *on* or *off* the plant.

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In general, fruits can be classified as either climacteric or non-climacteric based on their respiration pattern during ripening. Climacteric fruits display a characteristic peak in respiratory activity during ripening. It is interesting to note that climacteric fruits, such as banana and papaya tend to ripen rapidly which has led to the regulation of respiration as a possible means of biochemical manipulation of shelf life. In contrast, non-climacteric fruits such as pineapple, orange and star fruit simply exhibit a gradual decline in their respiration during ripening and therefore it has to be harvested at the optimum edible stage of maturity. However, no information is available on the respiration pattern of jatropha fruits during ripening. Therefore, this paper reports the intention to unravel ripening heterogeneity problems and indicates the fruit respiratory pattern of this crop.

MATERIALS AND METHODS

Source of Jatropha Trees and Fruit Bunches for Ripening Uniformity Study

The source of Jatropha trees and fruit bunches for this study was from a selected accession at two jatropha pilot projects in Sabah state of Malaysia. The pilot projects are Jatropha pilot project belonging to Sabah Department of Agriculture at Tenom Research Station and Jatropha pilot project belong to Sabah Land Development Board at Binakan Sook Keningau. Both pilot projects started first planting in March 2008. The data was collected at the end of March 2009 when the trees were exactly one year old. In this survey, only five trees for each ten accessions were randomly selected for jatropha trees ripening uniformity study and fifteen bunches with little ripened fruit were randomly harvested from seven selected accessions for bunches ripening uniformity study. The number of samples was limited because technically, counting the total fruits based on maturity stages is notoriously time consuming.

Sabah, Malaysia is characterized by a humid tropical climate which is moist and wet throughout the year with heavy rainfall (2,500 to 5,000 mm p.a.), average daily temperatures of 21-32 ^{o}C and humidity averaging about 85%. Due to small seasonal variation in incoming solar radiation, the annual difference in daylength is only 2 minutes along the equator and 49 minutes in northern regions, giving a daylength of 12.30 hours year round (Nieuwolt, l982). Rainfall is affected by the North - East (November - March) and South - West (June-August) monsoons which result in heavy rainfall. For the months April-May and September-October, less rain is experienced because of changes in monsoonal winds.

Ripening Heterogeneity Measurements

Jatropha ripening index was first established by modifying the guava colour index (Silip, 2003) where index 1 = immature fruit or small dark green fruit, index 2 = full-sized green fruit or mature green, index 3 = more green than yellow, index 4 = more yellow than green, index 5 = yellow fruit, index 6 = more yellow than black, index 7 = more black than yellow, index 8 = black fruit and index 9 = dry fruit. Percentage of fruits according to the established ripening index was assessed by calculating the percentage number fruits of similar maturity or similar ripening from the total number of fruits in a group such as per trees or bunches. The formula for this calculation is as follows:

$$\% \text{ Fruits} = [(St.y) / (At1)] \times 100$$

Where: At1= the total number of fruits in the whole trees or bunches and St.y= the total number of fruits of a specific index.

Samples for Respiration Study

Mature green, uniform sized (10 $\pm$ 0.5 mm girth, 10.25 $\pm$ 0.5 mm length) and uniform weight (13.5 $\pm$ 0.5 g fruit^{-1}) was harvested from two sources of samples. Samples for no pre-handling treatment were harvested from Bogor University Farm which is 10 minutes away from the laboratory. Pre-handling treatment samples were brought from the Jatropha Plantation at Serang, Banten, Indonesia. These samples were unavoidable subjected to eight hours of open air transportation from the farm to the laboratory. Pre-handling interruption hours before respiration test of the pre-handling treatment fruits are 28 hours. Fruits were kept in the respirometer bottle from the open topside and were kept closed with the lid while inserting neoprene gasket in between. The three storage temperature used were 27 $\pm$ 3 ^{o}C, 15 $\pm$ 3 ^{o}C and 7 $\pm$ 3 ^{o}C. Only the well formed and free from blemishes fruits were selected for experiment. Mature green in this study was identified from bunches that showed at less one of its fruits were yellow (ripe) or black (senescence).

Carbon Dioxide Measurement

The gas inside the airtight respirometer bottle having a volume of 3300 mL was measured using Infrared Continuous Gas Analyzer Model IRA-107 (Shimadzu, Japan). Gas composition was analyzed at intervals depending on the storage temperature. A preliminary experiment was done to determine a suitable time interval in hours for measurement of CO_2 and the minimum weight of fruits per respirometer bottle. Gas measurement was stopped when the fruits fully senescence or black in color.

Calculating Respiratory Rates

The respiration rates in terms of CO_2 at any given temperature were calculated using the following equation as given by Kays (1991). Respiration rate (mL kg^{-1} hr^{-1}) = [(Δ % x 10)(free space volume of respirometer bottle in liters)] / [(product fresh weight in kg)(time respirometer bottle is closed in hours)]. Where $\Delta = \Delta CO_2$ or concentration at time 2 – concentration at time 1. Milliliters of gas are converted to milligrams to account for the effect of temperature on the volume of gas through temperature correction.

Experimental Design and Data Analysis

Factorials complete randomized design with two type of samples (no delay and has a delay in handling before experiment) and three storage temperatures (27 $\pm$ 3 °C, 15 $\pm$ 3 °C and 7 $\pm$ 3 °C) was designated for study on respiration with five replications (n=30). Study on the ripening heterogeneity is non-experimental quantitative research type with variables were identified but not manipulated. Five trees for each ten selected accessions were identified for fruits ripening heterogeneity on the tree study (n=50), while fifteen bunches from seven selected accessions (n=105) were identified for study on fruit ripening heterogeneity on the bunch. The collected data was analyzed descriptively which min value was obtained, summarized and described.

RESULTS AND DISCUSSION

Fruits Ripening Heterogeneity in Whole Trees of Various Jatropha Accessions

Fruit ripening uniformity in whole tree of ten selected Jatropha accessions was determined. The study showed that irrespective of accessions, the trees always showed fruit ripening heterogeneity (Figure 1). On average, 50% of fruits in any single tree were of ripening index one, and decreased to 2% at ripening index six followed by an increase in number of fruits with increase in ripening index to about 10% at final stage of senescence, which is at black dry fruit or ripening index nine. A lower percentage of fruits at ripening index six were expected because the farmers at the sampling source had been practising regular harvest of fruits at ripening indices four, five and six. Number of fruits at index seven to nine were slightly higher even though farmers has been practising regular harvest at index four to six due to the fact that those fruits were senescence at the time of harvesting and therefore were purposely left on the tree. It is important to note that the farmers were only harvested those fruits as implied the best stage for seedling purposes. Higher percentage of fruits at ripening index one was also expected because this stage includes the immature fruits or young fruits.

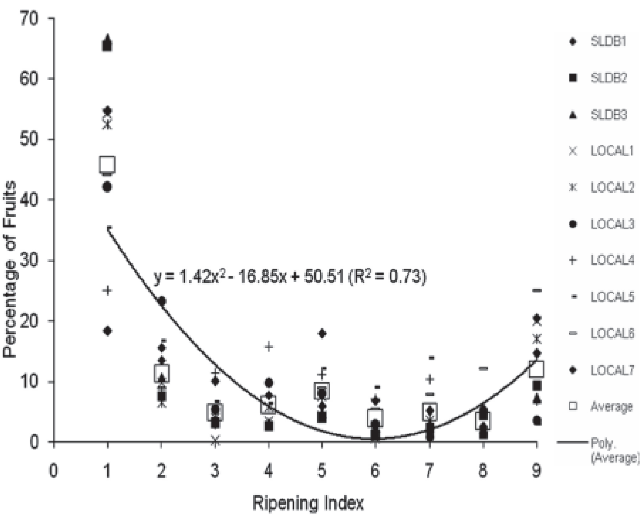

Figure 1. Percentage of fruits according to ripening index of selected *Jatropha curcas* L. accessions trees. Solid line represents a significant polynomial model at P<0.05

The results of this study are in agreement with reports of previous studies that Jatropha fruits ripen on its trees are not uniform (Silip and Tambunan, 2009; Biswas *et al.,* 2006; Heller, 1996). A high relationship (R^2 = 0.73) between the percentage of fruits with the ripening indexes in this study demonstrated the degree of ripening heterogeneity occurrences in this crop (Figure 1). The method used to explain maturity, ripening and senescence heterogeneity in this study showed an alternative method to measure these phenomena. The importance of ripening index in post-harvest handling of many horticultural produce is well known for many years. Ripening index standards has been developed in many countries as internal national standards. International ripening index standard for many horticultural produce are also available and can be found at CODEX alimentarius.

As abovementioned, concern over the ripening heterogeneous problems in this crop was unquestionable when it related to harvesting problems. Long term solutions could be by controlling all factors related to the problem such as genetic (Ginwal *et al.,* 2005), site characteristics (rainfall, soil type and soil fertility) (Francis *et al.,* 2005; Openshaw, 2000; Aker, 1997), plant age (Heller, 1996) and management (Heller, 1996; Sharma *et al.,* 1997). According to Bruns (2009) the phenophases in plants depends on the interaction between various phytohormones with the environment.

Fruits Ripening Heterogeneity in Selected Bunches of Selected Jatropha Accessions

Fruits ripening heterogeneity in selected bunches of selected jatropha accessions were determined because some reports in the literature recommend harvesting of bunches instead of individual fruits. This recommendation would reduce harvesting drudgery and time. The results of this study showed that irrespective of accessions, fruits ripening were not uniform in any single bunch. A high percentage of fruits ripening were observed at ripening index five or fully yellow fruit of around 25% and lower percentages were at both ripening indices one and nine with values of only 1% and 3% respectively. The relationship between percentage of fruit and ripening index was best described by a polynomial model with a high correlation of 80% (Figure 2). Jatropha bunches fruit ripening heterogeneity in this study showed that this problem is a natural phenomenon in this crop. Therefore, this study corroborates many previous reports that fruit ripening in this crop is not only heterogeneous on the tree but also on the individual bunches.

If this natural phenomenon is taken into account for the harvesting recommendation, it is believed that more information is still required to come up with a practical harvesting and post-harvest handling recommendation.

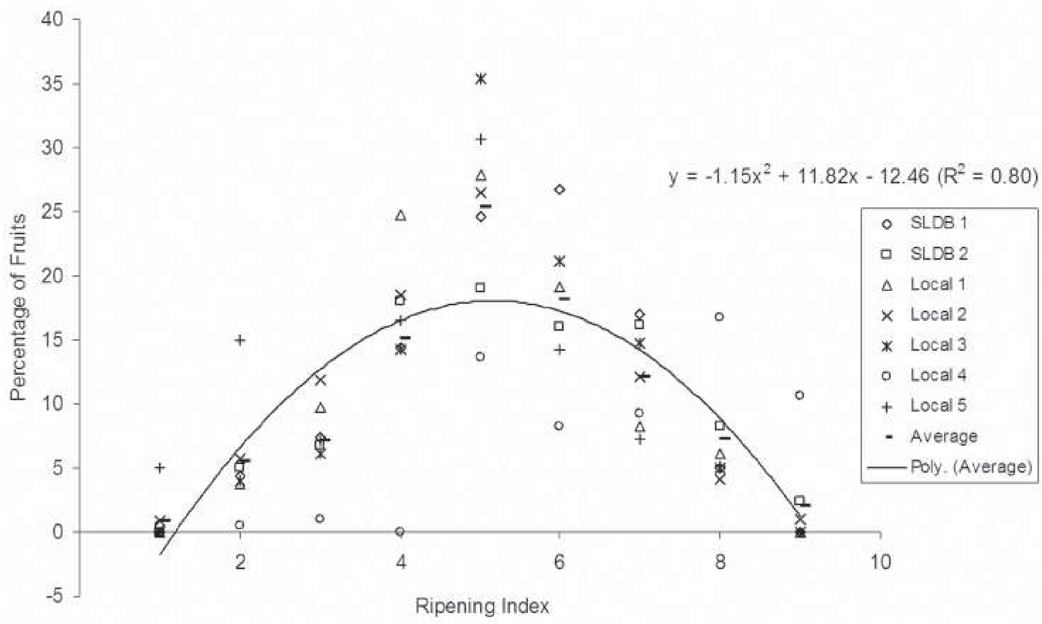

Figure 2. Percentage of fruits according to ripening index of selected *Jatropha curcas* L. bunches varieties. Solid lines indicate a significant polynomial model at P<0.05

Our interest on the harvesting recommendation of bunches will deal with unripe and over ripe fruits. Unripe fruits might require sorting and postharvest ripening treatments. However no such treatment was available in the current literature for Jatropha. In addition, recommendations on which ripening index that will result in high quantity and quality of CJCO for biodiesel feedstock is still not clear. It is also important to note that there are physiological and biochemical differences between fruits attached to and off the tree. According to Wills *et al.,* (1998) the development and maturation of fruit is completed only when it is attached to the plant, but ripening and senescence may proceed *on* or *off* the plant. Therefore, this study opens up many future research possibilities in the area of post-harvest physiology.

Respiration Pattern of Jatropha Fruits

The respiration data corresponding to different storage temperatures and different samples indicated an appearance of upsurge in CO_2 concentration (Figure 3). The results of this experiment confirm that jatropha fruits are in the class of climacteric fruits. The point of upsurge in the CO_2 concentration was different based on storage temperature. The peak was observed as early at 54 h at storage temperature of 27 $\pm$ 3 ^oC but it was only observed at 90 and 116 h at storage temperatures of 15 $\pm$ 3 ^oC and 7 $\pm$ 3 ^oC respectively. The present time consuming problem related to harvesting of jatropha fruits is due to the recommendation of harvesting only yellow and black fruits. The alternative now is to harvest the mature green fruit. It is important to

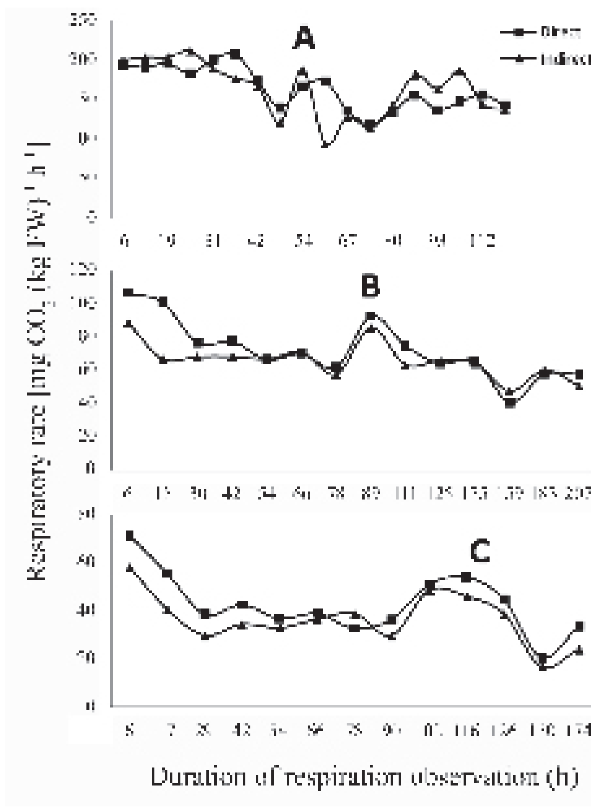

Figure 3. Respiratory rate of jatropha fruit at three different storage temperatures (A = 27 $\pm$ 3 ^oC, B = 15 $\pm$ 3 ^oC and C = 7 $\pm$ 3 ^oC) and two different postharvest handling of samples (directly harvested and used for experiment and delay in 28 h after harvesting before used for experiment)

note that a must in harvesting mature fruits is a prerequisite in some cultivars (avocado and mango) due to the fact that respiratory upsurge was reported to be inhibited while the fruit is attached to the tree (Kays, 1991). Therefore, the results of this study offer opportunities for future studies on jatropha fruits postharvest ripening treatment and its effects on the quantity and quality of CJCO.

CONCLUSION

Jatropha curcas L. fruits ripen on trees and bunches are not uniform. Irrespective of Jatropha accessions, the majority of fruits in any single tree were at ripening index one and lower at ripening index five, six and seven. However, many of the fruits were at ripening index four, five and six when ripened bunches were selected at harvest. The results of respiration tests showed that jatropha fruits are climacteric.

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